M.O.751
METEOROLOGICAL OFFICE

the meteorological magazine

FEBRUARY 1964 No 1099 Vol 93
Her Majesty's Stationery Office

RESEARCH OFFICER

East African Agriculture and Forestry Research Organization

Applications are invited for an appointment as a research officer, under 45, with an honours degree in Physics or Mathematics and with post graduate experience to Ph.D. Standard in Meteorology or Agricultural Physics. The candidate selected will be required to take part in a programme of agricultural meteorological research involving studies of evapo-transpiration and heat balance, using a mobile meteorological laboratory, to tackle problems of shade climate in plantation crops, hail incidence and damage, etc. The candidate will be expected to be able to design, install, adapt and use equipment, sometimes under adverse conditions, which will call for adaptibility and resource.

The appointment will be on contract for either one or two tours each of two years. Salary in scale £1,221–£2,172 p.a. according to experience, plus 25% gratuity. Free family passages, medical attention, accommodation at low rental, generous leave and children's education allowance.

Apply to

DIRECTOR OF RECRUITMENT,
Department of Technical Co-operation,
Eland House, Stag Place, Victoria, S.W.1

giving full name, age and qualifications and quoting RC 264/348/03.

METEOROLOGICAL OFFICE M.O.751

THE METEOROLOGICAL MAGAZINE

Vol. 93, No. 1099, February 1964

551.509.33:06

A VISIT TO THE EXTENDED FORECAST BRANCH OF THE UNITED STATES WEATHER BUREAU

By J. M. CRADDOCK

During the past ten years, while I have been engaged on research in the Meteorological Office into the possibilities of long-range weather forecasting, I have met and corresponded with a good many of the scientists engaged in similar work in other parts of the world. Among them was Mr. Jerome Namias, Chief of the Extended Forecast Branch of the United States Weather Bureau, and in May and June 1963 I was able to visit him on his home ground, and to see how the methods described in his published work are actually put into effect. Unfortunately, Mr. Namias himself was taken ill about a week after my arrival, and did not return to duty for over three months, so I had only a few discussions with him. However, I had conversations with nearly all his colleagues, and attended several conferences and was able to form a very clear impression of the Extended Forecast Branch at work.

It is worth remarking here that long-range weather prediction is an inherently more difficult problem than short-range forecasting which itself is difficult enough. Firstly our understanding of the principles involved is comparable with the understanding of the principles of short-range forecasting which existed at the time of Admiral FitzRoy before the advances made in the last 100 years. Secondly the meteorological data exchanged on the international communications network are intended mainly for the short-range forecaster, and are not arranged conveniently for use in long-range work and finally, because each large-scale development lasts a considerable time, the student of long-range changes cannot rely entirely on his own memory, but must supplement it by a library of relevant information in a form suitable for quick reference. Hence any unit intending to make real progress in this field must have three things: a general method of attack which, because of our imperfect understanding of the basic physics, must be capable of modification in the light of experience; an organization for sifting, averaging and otherwise processing the myriads of data intended for short-range purposes into a much smaller number of data which are or may be relevant to the long-range problem; and a versatile library of background information to serve as a long-range memory. To these might be added a sound procedure for checking and assessment.

The fulfilment of these requirements, particularly those for data processing and the background library, are beyond the resources of nearly all private individuals and most small meteorological services, and it is not surprising that the Extended Forecast Branch of the United States Weather Bureau should be one of the most active units in this field.

The physical location of the Extended Forecast Branch is at Suitland, Maryland, in one of a group of U.S. Goverment buildings on the outskirts of Washington, D.C. The building is shared with other branches of the Weather Bureau, including the main library and, most important, that part of the Joint Numerical Weather Prediction Unit which produces short-range forecasts by computer. As a result, the Extended Forecast Branch receives a large proportion of its working material in the form of punched cards and magnetic tapes, checked and ready for the computer, which are prepared originally for use in short-range forecasting. Further, the Branch has access to the very fast IBM7094 computer which is used for short-range numerical forecasting, and has exclusive use of two small IBM1401 computers. The facilities for data processing are therefore excellent.

The main work of the Extended Forecast Branch is the preparation of forecasts of the mean conditions for periods of 5 days and 30 days ahead, and the basic method consists in each case of the estimation of future changes from a series of northern hemisphere charts of the observed height of the 700 mb surface averaged over the same time interval. In other words, the averaging over 5 days or 30 days is intended to smooth the large, rapidly changing features which dominate the daily upper air chart while leaving the more lasting features which must change progressively into those of the chart for the forecast period. The experimental work on 90-day forecasts similarly makes use of 90-day mean charts but differs from the other procedures in laying more stress on correlations, contingencies and qualitative reasoning associated with interactions between the atmosphere and the underlying surface.

The choice of an upper air chart as the basic tool for long-range forecasting has the consequence that the period covered by the background library, or by the long-range memory, is comparatively short, since it is confined to the years for which realistic upper air charts can be drawn. Hence it is difficult to find good analogues for the current situation, although the library is well organized to make use of what material there is. Another consequence is that the forecast upper air chart, when it has been arrived at, has to be interpreted to give the real objects of interest for most consumers, namely, the anomalies of temperature and rainfall in different parts of the United States. For this purpose the national territory is divided into 40 districts, most of them coinciding with the individual states. A forecast of the anomalies of temperature and precipitation is produced by the Extended Forecast Branch and shows smooth variations over the whole of the United States. This forecast is sent to the District Forecast Centres where the forecasters interpret and sometimes modify it for their own uses.

The staff of the Extended Forecast Branch number about 40. Work on 30-day and seasonal forecasting, which is described later, is under the direct control of Mr. Namias. Subject to his general guidance, his scientific colleagues head the groups which carry out the rest of the work.

Five-day forecasting, which forms the largest activity, is carried out by a roster of six forecasters under Mr. Charles Woffinden. During my stay Mr. Woffinden was absent and his place was taken by Mr. James O'Connor. Three forecasts are issued each week, on Sundays, Tuesdays and Thursdays, and these are sent as guidance forecasts to the main forecasting centres in the United States. (They are also received overseas, for example, at Bracknell.) The forecast period starts at the time when a 48-hour outlook ends, so that if, for clarity, we designate the day the forecast is made by D, the forecast is of average conditions from $D + 2$ up to $D + 6$, or a 5-day period centred on $D + 4$. The basic material is a series of 5-day mean charts for overlapping periods of which the most recent, based wholly on observed material, is centred at $D - 3$. Thus the forecaster has to extrapolate the changes on his series of observed charts for a further 7 days. To help him he has several auxiliary charts based partly on observed data and partly on short-range numerical forecasts. He also has an auxiliary chart based on the assumption that 5-day mean upper air features will be advected by barotropic processes on an unchanging 30-day mean pattern which characterizes the current state (and may be considerably different from the climatic normal).

Not only the chart analysis but also the chart drawing is carried out by computer. The IBM7094 has as one means of output a mechanical curve follower, which, once a blank chart is put in place, draws a set of isopleths far more smoothly and rapidly than can be done by hand. This facility is used to present the observations in every form which may be useful. For example, a northern hemisphere field of the 700 mb height may be charted directly as a departure from normal or as a tendency field from the preceding field. The same treatment is given to northern hemisphere charts of the air pressure at sea level. Similar representations are used for the fields of temperature and rainfall over the United States, and zonal indices are regularly calculated and displayed. The forecaster has to reconcile the various indications, and this he does on the basis of judgement and experience of 5-day mean charts gained during the last 10–15 years. His first essay at the forecast 700 mb northern hemisphere chart is translated in terms of temperature and rainfall anomalies in the United States, and these are compared with estimates made by statistical methods which have been developed by Mr. W. H. Klein. All the material is considered at a conference attended by scientists of the Branch, and the forecaster amends his preliminary forecast as far as he thinks necessary. The final forecast includes, not only the mean forecast 700 mb contour field for the northern hemisphere for the 5-day period, but a similar forecast of the mean pressure field at sea level and the distribution of temperature and rainfall anomalies over the United States. It also includes a separate pressure and frontal field for each of the 5 days, but these are to be looked on as showing the type of air mass and pressure change to be expected in each area rather than the actual weather systems.

A related activity is work on development and verification, which goes on under Mr. William H. Klein. Mr. Klein[1] has done a great deal of statistical groundwork on subjects such as depression tracks. In the last few years he has been dealing mostly with the development of objective numerical methods of forecasting the temperature, pressure or rainfall in each forecast area of the

United States in terms of predictors such as the 700 mb height at a grid of points over the northern hemisphere, measured either simultaneously or some days earlier. He uses the screening procedure, a variety of multiple regression analysis, which sets out to extract from a very large number of possible predictors a much smaller number of predictors which give almost as good results. The repetition of such an analysis for each of 40 forecast areas in the United States for each of several weather elements represents a very large effort in computation, which is practicable because of the availability of the 7094 computer. The method of approach makes possible the sifting of useful predictors from irrelevant ones, and while his results do something to confirm the use of an upper air chart as the basic tool for prediction, they also indicate the desirability of including additional predictors.

Working with Mr. Klein, Dr. Don Gilman is concerned with forecast verification. Five-day mean forecasts of 700 mb height are verified for a grid of points covering most of the northern hemisphere, while those of temperature and precipitation are verified for the United States only. Success in forecasting the change in 700 mb contour height is nearly everywhere positive, but is higher in some areas than in others, being higher, for example, over Great Britain and most of North America than it is over strongly baroclinic areas such as the Gulf of Alaska and the Atlantic off the eastern seaboard of America. Success in forecasting 5-day mean temperatures is generally higher than that of a control forecast based on a short-range forecast plus persistence. As regards 5-day rainfall, the forecasts seem to show success in all seasons except summer. The various methods of forecasting which go to make up the technique have been tested separately, and it is interesting that none of them are as successful as the official forecasts. It seems, therefore, that the judgement of the forecasters does make a positive contribution to the standard of the forecasts. Besides carrying out much other work on forecast verification and probability statements, Dr. Gilman is also examining the possibility of predicting 30-day mean temperatures and rainfall by statistical methods.

Research work in the Extended Forecast Branch, which is directed by Mr. Phil Clapp,[2] is mainly concerned with the development of a simplified atmospheric model proposed by Dr. Julian Adem.[3] The model is intended to have the same characteristics as regards heat exchange as the real atmosphere, but with the functions of dynamical process in effecting heat exchange being replaced by an austausch coefficient. With this simplification, the mathematics become reasonably tractable, and it is hoped that the use of actual initial and boundary conditions will lead to predictions of the normal seasonal changes. There is a great deal of work to be done before it is clear whether the experiment is a success, but it is encouraging that work so far has shown the importance, under the assumptions made, of heat storage in the oceans.

The computer operations of the Extended Forecast Branch are carried out by a separate unit under the direction of Mr. Billy Lewis. Mr. Lewis is a trained meteorologist, but also an expert programmer who is able to relieve the other scientists of the Branch of all the specialized but essential work such as the preparation of data and the actual operation of the computer.

Work on 30-day and seasonal forecasting is carried out by Mr. Namias himself, or under his personal direction assisted especially by Mr. Klein and

Mr. Robert Dickson. The 30-day forecasts, which are issued at the beginning and middle of each month are produced by methods very similar to those used for 5-day forecasting, although of course the part played by short-range numerical forecasts is less. A full description of the method used ten years ago has been published by Namias in 1953[4] and the changes since then seem to be due more to the improvements in computer facilities and the availability of short-range numerical forecasts than to any major alteration of approach. However, feed-back phenomena from surface to atmosphere, such as sea surface temperature abnormalities, or snow cover, are considered to bolster or negate other indications. Namias[5] has illustrated an example. The first objective is the mean chart, for the forecast period, of the 700 mb contour heights over the northern hemisphere, and this is used to predict the broad distribution of above and below normal temperatures over the United States, and more roughly, over the rest of the northern hemisphere. To arrive at the first objective, several auxiliary charts are produced, each showing the expected position of the 700 mb troughs and ridges on some reasonable hypothesis, for example that the movements apparent on the most recent observed charts will be continued through the forecast period. Similar predictions are made of several zonal indices, and of the pressure distribution at sea level. However, if these auxiliary charts show disagreement, and they nearly always do, the task of reconciling them depends mainly on the judgement of the forecaster. He also has, for each forecast district in the United States, a number of contingency tables connecting the temperature and rainfall anomalies for different months, and if he knows, for example, that in a certain region a warm August has very rarely been followed by a cold September, he will be reluctant to make a September forecast of the 700 mb contour pattern with a cold trough in that region if August has been warm. Even when the mean 700 mb contours have been forecast, these have to be translated to give the expected anomalies of temperature and rainfall at the ground surface. The equations for doing so have been developed for forecast areas in the United States. For some purposes, those calculated for 5-day forecasting have been used and found satisfactory. For other parts of the northern hemisphere much cruder estimates are made, and unlike the forecasts for the United States, these are not checked after the event. There seems no doubt that the technique, as at present carried out, should show a higher standard of success over the United States than over any other part of the northern hemisphere. An official verification for the United States was published[6] in 1961.

Work on seasonal forecasting, which is mainly experimental, is similarly based on the use of time-mean charts, long-term relationships and contingency tables. However, it is still at an early stage.

The work of the Extended Forecast Branch also includes the routine production of 72-hour forecasts and descriptions of the past month's weather for the *Monthly Weather Review*. It therefore combines functions which in Britain are shared between several branches of the Meteorological Office.

This account falls far short of being a full description of the work of the Extended Forecast Branch, although I have tried to give a fair impression of the whole. I must, however, pay tribute to the scientists who so generously gave their time to discussions with me and to the friendliness with which I was received in America.

REFERENCES

1. KLEIN, W. H., LEWIS, B.M. and CROCKETT, C. W.; Objective forecasts of daily and mean surface temperature. *Mon. Weath. Rev., Washington D.C.*, **90**, 1962, p. 11.
2. CLAPP, P. F., WINNINGHOFF, F. J. and FISHER, G. E.; Vertical distribution of atmospheric heating and cooling at Washington, D.C., June & July 1961. U.S. Weather Bureau, *Tech. Mem. No.* 21, *Washington D.C.*, 1962.
3. ADEM, J.; On the theory of the general circulation of the atmosphere. *Tellus, Stockholm*, **14**, 1962, p. 102.
4. NAMIAS, J.; Thirty-day forecasting: a review of a ten-year experiment. *Met. Monogr., Boston, Mass.*, **2**, 1953.
5. NAMIAS, J.; Large scale air-sea interactions over the North Pacific from summer 1962 through the subsequent winter. *J. geophys. Res., Richmond, Va.*, **68**, 1963, p.6171.
6. Washington D.C., U.S. Department of Commerce Weather Bureau. Verification of the Weather Bureau's 30-day outlooks. *Tech. Pap. No.* 39, *Washington D.C.*, 1961.

551.501.45:551.509.322.7:311.214:519.2

NOTE ON THE PROBABILITY DISTRIBUTION OF WIND DIRECTION WITH APPLICATIONS TO ERRORS OF FORECAST WINDS

By A. F. CROSSLEY, C. L. HAWSON and J. A. HARKER

When a family of vectors has a Gaussian distribution it can be completely expressed in terms of the mean vector $\bar{\mathbf{V}}$ and the standard vector deviation σ of the individual vectors about the mean vector. The probability of the direction of any one of the vectors differing by not more than some specified angle α from the direction of the mean vector can be derived from the two parameters $\bar{\mathbf{V}}$ and σ as described below.

Let $\mathbf{V}$ be a vector inclined at some angle to $\bar{\mathbf{V}}$, and let $P(\alpha)$ be the probability of the direction of $\mathbf{V}$ differing by not more than an angle α from that of $\bar{\mathbf{V}}$. In Figure 1, $\bar{\mathbf{V}}$ is represented by OA, OC makes an angle α with OA, $\mathbf{V}$ is

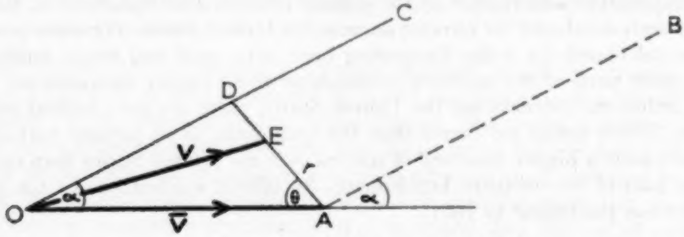


FIGURE 1—RELATIONSHIP BETWEEN VECTOR $\mathbf{V}$ AND MEAN VECTOR $\bar{\mathbf{V}}$

is represented by OE, and AE (produced if necessary) meets OC at D. Denote by r the distance AE and denote by θ the angle between AO and AE. For a Gaussian distribution of $\mathbf{V}$ about $\bar{\mathbf{V}}$,[1]

$$P(\alpha) = \frac{1}{\pi\sigma^2} \iint r \exp\left(-\frac{r^2}{\sigma^2}\right) \mathrm{d}r\, \mathrm{d}\theta \qquad \ldots (1)$$

where σ is the standard vector deviation of $\mathbf{V}$ about $\bar{\mathbf{V}}$; r is the magnitude of the vector difference between $\mathbf{V}$ and $\bar{\mathbf{V}}$; and the integration is over the area enclosed between OA and OC both extended to infinity, and a similar area reflected in OA.

Construct AB parallel to OC. In the area enclosed between OC and AB, when the value of θ is given, r ranges from o to AD, where

$$\frac{\mathrm{AD}}{\sin \alpha} = \frac{|\nabla|}{\sin (\theta + \alpha)} \qquad \ldots (2)$$

and the contribution to (1) is

$$\frac{2}{\pi \sigma^2} \int_0^{\pi - \alpha} \int_0^{\mathrm{AD}} r \exp\left(-\frac{r^2}{\sigma^2}\right) dr\, d\theta$$

which by use of (2) becomes

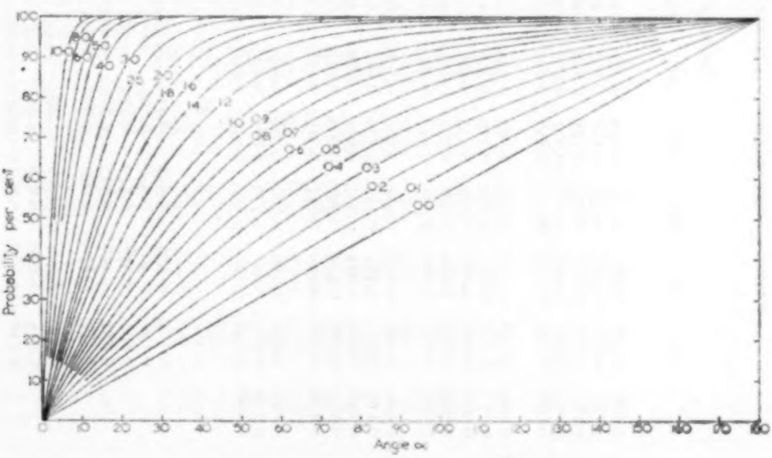
$$\frac{1}{\pi} \int_0^{\pi - \alpha} \left[1 - \exp\left(-\frac{|\nabla|^2}{\sigma^2} \frac{\sin^2 \alpha}{\sin^2(\theta + \alpha)}\right)\right] d\theta \quad .$$

In the area enclosed between OA produced and AB, r is unrestricted and the contribution to (1) is simply α/π.
Hence

$$P(\alpha) = 1 - \frac{1}{\pi} \int_0^{\pi - \alpha} \exp\left(-\frac{|\nabla|^2}{\sigma^2} \frac{\sin^2 \alpha}{\sin^2 (\theta + \alpha)}\right) d\theta \ , \qquad \ldots (3)$$

an expression which is in agreement with one given without proof by P. Graystone.[3]

Values of $P(\alpha)$ were determined from equation (3) on the Meteorological Office electronic computer METEOR for selected values of α and the ratio $|\nabla|/\sigma$ by use of Weddle's[4] formula with the range of integration divided (for the most part) into 90 equal segments. The results are shown in Table I and are plotted graphically in Figure 2. Tests using different numbers of sectors for the



Curves marked with values of $|\nabla|/\sigma$

FIGURE 2—PROBABILITY DISTRIBUTION IN A GAUSSIAN FAMILY OF VECTORS

TABLE I—PROBABILITY DISTRIBUTION OF DIRECTION IN A GAUSSIAN FAMILY OF VECTORS

Angle (α) between vector $\mathbf{V}$ and mean vector $\overline{\mathbf{V}}$

$\lvert\overline{\mathbf{V}}\rvert/\sigma$	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
									probability									
0.0	0.028	0.056	0.083	0.111	0.139	0.167	0.194	0.222	0.250	0.278	0.306	0.333	0.361	0.389	0.417	0.444	0.472	0.500
0.1	0.033	0.065	0.098	0.132	0.165	0.197	0.229	0.260	0.291	0.322	0.353	0.383	0.413	0.443	0.472	0.500	0.529	0.556
0.2	0.037	0.077	0.116	0.154	0.191	0.228	0.265	0.301	0.336	0.370	0.403	0.436	0.467	0.498	0.527	0.556	0.584	0.611
0.3	0.044	0.090	0.134	0.178	0.221	0.263	0.304	0.343	0.382	0.419	0.454	0.489	0.521	0.553	0.583	0.611	0.638	0.664
0.4	0.052	0.103	0.154	0.204	0.252	0.299	0.345	0.388	0.430	0.469	0.507	0.542	0.575	0.607	0.636	0.664	0.690	0.714
0.5	0.060	0.117	0.175	0.231	0.285	0.337	0.387	0.434	0.478	0.520	0.558	0.594	0.628	0.659	0.687	0.713	0.738	0.760
0.6	0.067	0.132	0.197	0.260	0.319	0.376	0.430	0.480	0.527	0.570	0.609	0.645	0.678	0.708	0.735	0.759	0.782	0.802
0.7	0.075	0.148	0.220	0.289	0.355	0.416	0.474	0.526	0.575	0.618	0.658	0.693	0.725	0.753	0.778	0.801	0.821	0.839
0.8	0.083	0.165	0.244	0.320	0.391	0.457	0.517	0.572	0.621	0.665	0.704	0.738	0.768	0.794	0.818	0.838	0.855	0.871
0.9	0.092	0.182	0.268	0.350	0.427	0.497	0.560	0.616	0.666	0.709	0.747	0.779	0.807	0.831	0.852	0.870	0.885	0.898
1.0	0.100	0.199	0.293	0.382	0.463	0.536	0.601	0.658	0.708	0.750	0.786	0.817	0.842	0.864	0.882	0.897	0.910	0.921
1.2	0.119	0.234	0.343	0.444	0.533	0.612	0.679	0.736	0.783	0.822	0.853	0.878	0.899	0.915	0.928	0.939	0.948	0.955
1.4	0.137	0.270	0.394	0.504	0.601	0.682	0.749	0.802	0.845	0.878	0.904	0.924	0.939	0.950	0.959	0.966	0.972	0.976
1.6	0.157	0.306	0.443	0.562	0.663	0.744	0.808	0.857	0.893	0.920	0.940	0.955	0.965	0.973	0.978	0.983	0.986	0.988
1.8	0.176	0.342	0.490	0.617	0.719	0.798	0.857	0.899	0.929	0.950	0.965	0.975	0.981	0.986	0.989	0.992	0.993	0.995
2.0	0.195	0.377	0.536	0.667	0.768	0.843	0.896	0.931	0.955	0.970	0.980	0.987	0.991	0.993	0.995	1.000	1.000	1.000
2.5	0.242	0.461	0.640	0.773	0.865	0.923	0.957	0.977	0.988	0.993	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
3.0	0.288	0.539	0.728	0.853	0.927	0.966	0.985	0.994	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

$\lvert\overline{\mathbf{V}}\rvert/\sigma$	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	30°
							probability								
3.0	0.117	0.233	0.343	0.445	0.539	0.622	0.695	0.758	0.810	0.853	0.888	0.916	0.937	0.954	0.966
4.0	0.156	0.307	0.446	0.569	0.674	0.760	0.829	0.881	0.920	0.947	0.966	0.979	0.987	0.992	0.995
5.0	0.195	0.378	0.540	0.675	0.781	0.858	0.913	0.949	0.971	0.984	0.992	0.996	1.000	1.000	1.000
6.0	0.233	0.446	0.625	0.762	0.859	0.922	0.960	0.981	0.991	0.996	1.000	1.000	1.000	1.000	1.000
7.0	0.270	0.510	0.699	0.832	0.914	0.960	0.983	0.994	0.998	1.000	1.000	1.000	1.000	1.000	1.000
8.0	0.307	0.570	0.763	0.885	0.951	0.981	0.994	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000
9.0	0.343	0.625	0.817	0.924	0.973	0.992	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
10.0	0.378	0.676	0.861	0.951	0.986	0.997	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

TABLE I—PROBABILITY DISTRIBUTION OF DIRECTION IN A GAUSSIAN FAMILY OF VECTORS *continued*

$\lvert\bar{\mathbf{V}}\rvert/\sigma$	Angle (α) between vector $\mathbf{V}$ and mean vector $\bar{\mathbf{V}}$																	
	90°	95°	0100°	105°	110°	115°	120°	125°	130°	135°	140°	145°	150°	155°	160°	165°	170°	175°
	probability																	
0.0	0.500	0.528	0.556	0.583	0.611	0.639	0.667	0.694	0.722	0.750	0.778	0.806	0.833	0.861	0.889	0.917	0.944	0.972
0.1	0.556	0.584	0.610	0.637	0.663	0.689	0.714	0.739	0.764	0.788	0.812	0.836	0.860	0.884	0.907	0.930	0.954	0.977
0.2	0.611	0.638	0.663	0.688	0.712	0.735	0.758	0.780	0.802	0.823	0.844	0.864	0.884	0.904	0.923	0.943	0.962	0.981
0.3	0.664	0.689	0.713	0.735	0.757	0.778	0.798	0.817	0.836	0.854	0.872	0.889	0.905	0.992	0.938	0.953	0.969	0.985
0.4	0.714	0.737	0.759	0.779	0.798	0.817	0.834	0.850	0.866	0.881	0.896	0.910	0.923	0.937	0.950	0.963	0.975	0.988
0.5	0.760	0.781	0.800	0.818	0.835	0.851	0.865	9.879	0.892	0.905	0.917	0.928	0.939	0.950	0.960	0.970	0.980	0.990
0.6	0.802	0.820	0.837	0.853	0.867	0.880	0.893	0.904	0.915	0.925	0.934	0.943	0.952	0.961	0.969	0.977	0.985	0.992
0.7	0.839	0.855	0.870	0.883	0.895	0.906	0.916	0.925	0.933	0.941	0.949	0.956	0.963	0.970	0.976	0.982	0.988	0.994
0.8	0.871	0.885	0.897	0.908	0.918	0.927	0.935	0.942	0.949	0.955	0.961	0.967	0.972	0.977	0.982	0.986	0.991	0.996
0.9	0.898	0.910	0.920	0.929	0.937	0.944	0.950	0.956	0.961	0.966	0.971	0.975	0.979	0.983	0.986	0.990	0.993	0.997
1.0	0.921	0.931	0.939	0.946	0.952	0.958	0.963	0.967	0.971	0.975	0.978	0.981	0.984	0.987	0.990	0.992	0.995	1.000
1.2	0.955	0.961	0.966	0.970	0.974	0.977	0.980	0.983	0.985	0.987	0.989	0.990	0.992	0.993	0.995	0.996	1.000	1.000
1.4	0.976	0.980	0.983	0.985	0.987	0.989	0.990	0.991	0.992	0.993	0.994	0.995	1.000	1.000	1.000	1.000	1.000	1.000
1.6	0.988	0.990	0.992	0.993	0.994	0.995	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.8	0.995	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2.0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Note: $\lvert\bar{\mathbf{V}}\rvert/\sigma$ is the ratio of the magnitude of the mean vector to the standard vector deviation.

range of integration showed that the tabulated values of probability are not more than 0.001 in error, except that when a computed value exceeds 0.9950, giving an entry of 0.995 (rounded down) or greater, the remaining values for larger angles of α in the same row are entered as 1.000. This device was adopted in order to economize the time required on the computer.

The tabulations, which can be applied to any family of vectors with a Gaussian distribution, have practical applications to problems involving winds.

Upper level winds away from the influence of surface features are often distributed about the vector mean wind very nearly in accordance with the Gaussian law of errors (see for example C. E. P. Brooks, C. S. Durst, N. Carruthers, D. Dewar and J. S. Sawyer[1]). If, for example, it is required to find the probability of the wind departing by more than say 20° from the mean wind direction during a season for which the mean vector wind is 250° 32 knots and the standard vector deviation is 20 knots, simply determine the ratio $|\bar{\mathbf{V}}|/\sigma = 32/20 = 1.6$ and extract the value of $P(\alpha)$ appropriate to this ratio from the table for the required angular departure $\alpha = 20°$. This gives $P(20) = 0.56$. Thus the probability of the wind direction being inclined at an angle greater than 20° from the mean wind direction at any time in this season is 44 per cent. Alternatively during this season the wind blows at an angle greater than 20° from the mean wind during 44 per cent of the time.

The distribution of errors in forecast winds at most levels is also likely to approximate to a Gaussian distribution provided that the forecaster does not introduce bias, e.g. by applying some safety factor such as increasing speeds for headwinds, or overdeepening of depressions. The theory of errors suggests that the more sources of error there are the more likely is the distribution to be Gaussian. Thus the likelihood of a Gaussian distribution for the errors increases with the number of levels involved in the forecast. Such circumstances arise in problems involving radio-active fallout when the probability of some specified angular error in the predicted wind direction is of great importance. The distribution of errors in the forecast winds can be represented by the root mean square vector difference, σ_f, between the true wind $\mathbf{V}$ and the corresponding forecast wind $\mathbf{V}_f$. On those occasions when all the actual winds have the same value $\mathbf{V}$, the forecast winds $\mathbf{V}_f$ can be regarded as distributed about $\mathbf{V}$ with standard vector deviation σ_f; and conversely if a large number of occasions are separated out on each of which the forecast wind has the same value $\mathbf{V}_f$, then the corresponding actual winds can be regarded as distributed about $\mathbf{V}_f$ with the same standard vector deviation σ_f. Of course, for any particular forecast there will be only one result and consequently no error distribution; however, before the result is known the probability distribution enables the chance of this result lying within any specified range to be estimated. Thus for an individual forecast the probability distribution of the angular difference between the actual and forecast winds about the direction of the forecast wind can be obtained from the tables or graph and the ratio $|\mathbf{V}_f|/\sigma_f$. As an example suppose we require the probability of the actual wind direction lying between 270° and 290° when the forecast wind is 250° 40 knots and the standard vector error of the forecast system is 20 knots. Then the ratio $|\mathbf{V}_f|/\sigma_f = 40/20 = 2$ and for this ratio the probability of the actual wind direction lying between 270° and 250°, i.e. a veer of 0° to 20° from the forecast direction is

$\frac{1}{2}[P(20)] = \frac{1}{2}(0.67)$, and similarly the probability of a wind between 290° and 250° is $\frac{1}{2}[P(40)] = \frac{1}{2}(0.93)$. Hence the probability of the wind direction lying between 270° and 290° is $\frac{1}{2}(0.26) = 0.13$.

It should be mentioned that in this type of problem σ is dependent on the time interval between the validity time and the time of the latest observations available to the forecaster, as well as on the forecast techniques, levels and season involved. As a further refinement it would be useful to investigate how the standard vector deviation of the forecast errors varies with the forecast wind and the synoptic situation. Although in the main the procedure outlined should provide a sound statistical method for the determination of the probability of any specified angular error in a wind forecast, a few occasions will arise when the forecaster is able to make a subjective assessment which will be better than this statistical estimate of the likely errors, because he can see that in the particular circumstances the probability distribution will not be normal, e.g. when a sharp trough separating two quite different wind régimes is forecast to be close to the location for which the forecast wind is given. In the circumstances of this example the probability distribution of the angular errors will be bimodal about the forecast directions of the two wind streams and not Gaussian about one of them.

Note added in proof.—Mr. E. Knighting has pointed out in a private communication that

$$P(\alpha) + P(\pi - \alpha) = 1 + \operatorname{erf}\left(\frac{|\mathbf{V}|}{\sigma}\sin\alpha\right)$$

As the error function erf x is extensively tabulated, the range of integration required for the computation of $P(\alpha)$ can be restricted to $0 \leqslant \alpha \leqslant \pi/2$, with consequential saving in time required on the computer.

REFERENCES

1. BROOKES, C. E. P., DURST, C. S., CARRUTHERS, N., DEWAR, D. and SAWYER, J. S.; Upper winds over the world. *Geophys. Mem., London*, No. 85, 1950.
2. GRAYSTONE, P.; Mean winds to high levels over the British Isles. Unpublished.
3. COMRIE, L. J.; Chambers's shorter six-figure mathematical tables. London, W. & R. Chambers, Ltd., 1950, p. 352.

551.524.37:551.525.4

SOIL TEMPERATURES DURING THE FROST OF EARLY 1963 IN SOUTH-EAST ENGLAND—PART II

By E. N. LAWRENCE, B.Sc.

Summary.—Variation of soil temperature over short distances and diurnal variation are discussed. Comparisons are made between soil temperatures under grass and under bare soil, and finally some past climatological extremes are considered. Part I of this article was published in January of this year.[1]

Local or random site differences.—Differences may arise between soil temperatures at nearby sites with apparently identical 'standard' exposures.[2,3] In a Kew experiment, soil temperatures (at 0930 and 1500 GMT) at a depth of 1ft under level grass were measured at three sites within a radius of 20 yards and it was found that[3] "the standard deviation of the individual differences from the mean of the three readings was 0.16°F, and 96.4 per cent of the readings were within ± 0.3°F of the mean." Again, North American data[4] show differences on a summer day of up to about 2°C at a depth of 5.5 cm between sites within 20 metres, and over 5°C at a depth of 10 cm between sites 100–150 metres apart (albeit with different instrumentation). Thus a change of site is liable to be associated with differences in the soil temperature régime.

The new site (B) at Kew showed no freezing whatsoever in early 1963 at a depth of 1ft under grass (absolute minima 0.4°C, recorded with a Symons thermometer); indeed, absolute minima at this site were very similar to those for Rothamsted (clay). However, the soil temperature differences between sites A and B are probably the result of distinctly different exposures, soil types and conditions of soil (see introduction in Part I[1]). The somewhat artificial soil at site A is very different from that at site B which is distinctly heavier between depths of about 6in. and 3ft 6in. and only slightly disturbed (during the recent installation of soil thermometers). Also, site A has a free drainage while site B has an impeded drainage as evidenced by gleying* and iron and manganese mottles within the profile, at all levels down to a depth of 4ft. Furthermore, at site B but not at site A, there is a surface organic mat (1½ to 0 in.) which would act as a sponge under wet conditions but as an insulating layer when dry.

Site changes at Woburn are equally revealing. A reorganization at this station in October 1928 resulted in a marked change[4] at this time in the monthly deviations from the standard 1941–50 mean of the difference between earth temperatures at a depth of 1ft at Woburn (under grass) and at Rothamsted (under bare soil). The temperature excess of Woburn over Rothamsted changed from being a little greater in winter than in summer to distinctly greater in summer than in winter. The site change at Woburn resulted in distinctly lower temperature records in winter (by about 1½°F) and higher temperature records in summer (by about 2½°F)—relative to Rothamsted. A further change of site in 1958 appears to have caused a reversion towards the original (pre-1928) conditions.

Diurnal variation.—Although diurnal changes are inhibited under snow-covered winter conditions, some diurnal variation was apparent during early 1963. At Kew (site A), Woburn and Cardington in January 1963 under thick snow (see Tables I and III† in Part I), the maximum variation was about ½°C at a depth of 4in. and probably about half this value at a depth of 8in. Even at a depth of 1ft at Kew (site A), the diurnal change of temperature during the general cooling period preceding the absolute minima of January was indicated by a levelling out from about 1500 to 2100 GMT.

Daily *minimum* soil surface temperatures with no snow cover at Kew (site B) in early 1963 were often considerably lower than the corresponding air (screen) temperature minima, but 3-hourly observations of surface temperature suggest that the *maxima* were not so different: for example, during the period 2100 GMT on 2 March to 2100 on 3 March, the air temperature varied from −5.6°C to 10.4°C, while surface temperature varied from −8.8°C (minimum) to 9.5°C (at 1500). This relationship between air and surface temperatures is presumably seasonal and caused at least partly by the cold, damp soil, and perhaps partly by site differences—and precedes the pronounced March rise of soil temperature[4] referred to in Part I.[1]

---

*Gley is a technical term used to describe the characteristics of an imperfectly or poorly drained soil. When the soil is saturated with water, intense reducing conditions are created which are characterized by the presence of the grey colorations of ferrous iron. On exposure to air, the grey colours commonly change to brown. In the zone of a fluctuating water table, rusty mottles and grey colours occur together. Gleying is the process by which gley occurs.

†Tables I (*a*), (*b*) and (*c*), II and III are published in Part I in the January 1963 issue of the *Meteorological Magazine*.

Comparison of temperature under grass and under bare soil.—The insulating effect of grass cover is shown by the tendency for grass minimum temperatures to be lower than minimum temperatures on a bare soil surface: for example, on the night of 2–3 March 1963, the grass minimum temperature (2100–0900) at Kew was −10.6°C as compared with −8.8°C on bare soil—though this difference may be caused partly by site differences.

At Kew (site A) in January 1963, at depths of 4in. and 8in., freezing occurred earlier and penetrated more quickly under bare soil than under grass: at a depth of 4in., freezing under grass occurred some 1–2 days later while at a depth of 8in. the lag was 2–3 days. Conversely, both in late January and early March 1963 (some Kew data for the time of the mid-February thaw being missing), at depths of 4in. and 8in., thawing occurred later under bare soil than under grass-covered soil—about one day later at 4in. and about 2 days later at 8in. in the thaw of early March. Both bare soil and grass-covered soil showed the tendency for freezing and thawing to penetrate downwards from 4in. to 8in. at Kew (site A) during January 1963. In contrast with Kew, Rothamsted data for depths of 4in. and 8in. showed no significant difference between grass-covered soil and bare soil for the dates of freezing and thawing, but in clay soil, changes are inhibited generally.

During January 1963 at Kew (site A), absolute minima were slightly lower under bare soil than under grass while maximum 3-hour increases of soil temperature, maximum 3-hour and 24-hour decreases were all slightly greater under bare soil than under grass (Table I(*b*)). Likewise at Rothamsted (Table I(*c*)) for the period January to March inclusive 1963, the absolute minimum temperature was lower under bare soil at a depth of 4in. However, at 8in. the bare soil temperature was slightly higher, and at both these levels the minima for January 1963 were higher under bare soil (Table I(*c*)); but higher absolute minimum temperatures under bare soil are abnormal, as judged from Rothamsted long-term data (Table II).

Though the differences at Kew during 1963 may be attributed mainly to a greater mean diffusivity under bare soil because of higher thermal conductivity, it is noteworthy that under grass at depths of 4in. and 8in., soil temperatures arrived simultaneously at 0°C at the end of the second freezing spell in early March, whereas under bare soil, temperatures (at least at the observing hours) did not show such a tendency. This suggests better drainage[6,7] and more effective percolation under grass.

Past climatological extremes.—Reports of the depth of freezing soil, already described, suggest that new long-term extremes of soil temperature minima were recorded during early 1963. However the following facts emerge when the present Kew data are compared with similar though limited past data for the same site for 0900 GMT (1000 GMT before 1915):

(i) *Absolute* minimum soil temperatures for the recent winter are the lowest since records began, in July 1903; the previous record occurred in January 1940 (at 1ft under grass) and in March 1947 (at 4ft under grass) (Tables I(*b*) and II).

(ii) With reference to minimum *monthly mean* temperatures at Kew, also since July 1903, the lowest values occurred in February 1963 (32°F) and January 1963 (32.2°F, 0.1°C) at a depth of 1ft under grass, and in

February 1963 (38.1°F, 3.4°C) at a depth of 4ft under grass; the next lowest monthly mean values at Kew occurred in January 1940 (33.1°F, 0.6°C) at 1ft, and in February 1940 (39.2°F, 4.0°C) at 4ft.

However, at Regent's Park (0900 GMT observations for the period 1884-1910) there were even lower absolute minimum temperatures and lower monthly mean temperatures, namely in February 1895: 28.2°F (-2.1°C) and 30.9°F (-0.6°C) respectively, at 1ft under grass, and 34.8°F (1.6°C) and 36.7°F (2.6°C) respectively, at 4ft under grass. These were record values for Regent's Park except that the minimum monthly mean temperature at 4ft under grass reached 36.5°F (2.5°C) in January 1891 :but during these earlier winters at Regent's Park there was probably less protective snow cover[8,9,10] and less warming by artificial (urban) sources. All the data under discussion here seem to confirm that the period 1896 to 1937 was a period of exceptional immunity from difficult winter conditions.[11]

It may be seen from Table I (columns for depths of 1ft and 4ft, under grass) and Table II that in early 1963, a new extreme of soil temperature was recorded at a depth of 4ft at Woburn though not at a depth of 1ft where lower temperatures were recorded in January 1940. The lower soil temperature at a depth of 1ft during 1940 may well be due to changes of site at this station, described in an earlier section, and also to rather less protective snow cover in that year.

At Rothamsted (Tables I and II), absolute minimum temperatures at depths of 1ft and 4ft under grass during early 1963 were within 1°F of the long-period absolute extremes, which were recorded in the years 1929 and 1940 (at 1ft) and 1947 (at 4ft), but there was less protective snow cover during these years.

Past meteorological data in general are not sufficiently detailed to allow calculations of the extreme depths of frost penetration into soil, since the depth of freezing depends not only on air temperature but also on wind velocities, solar radiation and especially on snow cover; soil temperature at, say, a depth of 1ft may be regarded as the integrated effect of these variables. Soil temperture at a depth of 1ft together with details of snow cover provide a good indication of winter severity and discomfort.

Acknowledgements.—The author is indebted to the Director, Lawes Agricultural Trust, Rothamsted Experimental Station and to Mr. C. A. Thorold, B.Sc., Lawes Agricultural Trust, Woburn Experimental Station for the supply of special data used in this investigation, and to Mr. B. Wilkinson, M.Sc., Regional Soil Chemist, South-east Region, National Agricultural Advisory Service, Ministry of Agriculture, Fisheries and Food for the soil morphological data and much useful discussion, particularly on soluble salt content of soils.

REFERENCES

1. LAWRENCE, E. N.; Soil temperatures during the frost of early 1963 in south-east England. Part I. *Met. Mag., London*, **93**, 1964, p. 4.
2. SMITH, L. P.; Random errors in standard observations. *Met. Mag., London*, **80**, 1951, p. 236.
3. Meteorological Office. Averages of earth temperature for the British Isles. London, HMSO, 1960.
4. LETTAU, H. H. and DAVIDSON, B.; Exploring the atmosphere's first mile. Vol. I and II. London, Pergamon Press, 1957.
5. SARSON, P. B.; Variation of the difference between two earth temperatures. *Sci. Pap. met. Off., London*. No. 14, 1962.

6. LAWRENCE, E. N.; Singularities in the annual variation of air, grass and soil temperatures. *Met. Mag., London*, **83**, 1954, p. 235.
7. SARSON, P. B.; Exceptional sudden changes of earth temperatures. *Met. Mag., London*, **89**, 1960, p. 201.
8. SYMONS, G. J.; *Symons's met. Mag., London*, **25**, 1890, December; **26**, 1891, January; **30**, 1895, January and February.
9. CAMPBELL BAYARD, F. and MARRIOT, W.; The frost of January and February, 1895, over the British Isles. *Quart. J. R. met. Soc., London*, **21**, 1895, p. 141.
10. HAWKE, E. L.; Snow-cover in Great Britain, 1895 and 1947. *Quart. J. R. met. Soc., London*, **75**, 1949, p. 104.
11. LAMB, H. H.; What can we find out about the trend of our climate? *Weather, London*, **18**, 1963, p. 194.

551.507.352:551.508:06

THE HASTINGS AIRCRAFT OF THE METEOROLOGICAL RESEARCH FLIGHT

By D. R. GRANT

Introduction.—Since September 1950 the Meteorological Research Flight (MRF) has been carrying out experiments in the atmosphere at heights up to 20,000 feet in a Hastings C Mark I aircraft (Plate II). During this time many instruments had been fitted and subsequently removed after completion of the experiment for which they had been designed. Many of the cables and much obsolete bracketry remained and much of the equipment still in use did not comply with the latest safety regulations. It was, therefore, decided that a major re-design of the inside of the aircraft was required. At the same time it was planned to fit a number of new radio and navigational aids and some new meteorological equipment.

Preparations for the refitting went on for a number of months and the work on the aircraft was started in July 1962. By February 1963 the work had been completed, and after flight tests the aircraft was available for experimental work early in March 1963.

Re-design of interior.—The galley has been removed and the signaller's position has been moved to the rear of the fuselage. All the radio and navigational equipment is now housed in a specially built rack on the starboard side. Electrical supplies for radio and experimental equipment and a small amount of meteorological instrumentation are also installed on the starboard side (Plate III). The whole of the port side from behind the first pilot to the main door (Plate IV) is available for meteorological instruments and observers, apart from one seat occupied by the signaller.

Immediately behind the first pilot there is a forward facing seat which is occupied by the officer in charge of the experiment. Behind this seat are the instrument exposure positions. All instruments to be exposed in the airstream are mounted at the end of 1½-inch diameter steel tubes about 3 feet in length. These tubes are clamped to ramps inside the aircraft and the instruments can be moved out to a distance of about 2 feet through portholes in the side (Plate V). At least three instruments may be exposed simultaneously. Behind the ramps there is a seat for the observer operating them, and then come five tables, each with two seats for observers. All seats are fitted with intercommunication with a switch to select any of about 5 channels. One of these channels is reserved for the exclusive use of the observers and they can talk

freely without interruptions by aircrew communications. All tables are similarly supplied with power, viz. 28V d.c. aircraft supply, 24V d.c. stable battery supply, 115V 400 c/s 3 phase, and 230V 50 c/s single phase.

Meteorological instrumentation.—Temperature is still measured with the standard Meteorological Office (MO) electrical resistance thermometer. The element is fitted under the wing. Two standard instruments are fitted on the aircraft and three additional elements are installed one of which has a blanked-off front to protect it from precipitation and improve its performance in cloud. One of the other two is used for supplying a continuous temperature record to a multi-channel galvanometer recorder, and the other is connected to a self balancing bridge which has recently been developed and which is at present undergoing tests. On this instrument no manual balancing of the bridge is necessary and the temperature is displayed on a counter.

The lag coefficient of this thermometer element is about 8 seconds which means that it is insensitive to small-scale variations. For experiments in which detailed temperature structure is required, an ultra rapid thermometer can be fitted to one of the booms and its output is connected via an amplifier to the galvanometer recorder. Using this instrument, temperature changes can be recorded of 0.05°C occurring in 1/10 sec (i.e. in a distance flown of about 25 feet).

The MO frost-point hygrometer is available for measuring dew- and frost-points. As a reading on this instrument takes at least 30 seconds it is again unsuitable for measuring small-scale variations. For this purpose a micro-wave radio refractometer is used to measure the refractive index of the air. It is known that

$$(n - 1) \times 10^6 = \frac{77.6p}{T} + \frac{3.735 \times 10^5 e}{T^2} \quad \text{where}$$

n is the refractive index, p (mb) the atmospheric pressure, e the vapour pressure (mb) and T is the air temperature in °K. Thus if pressure and temperature are known, the vapour pressure can be obtained from the refractive index. The radio refractometer is not an absolute instrument and is also subject to zero drift, but its sensitivity is constant. Occasional simultaneous readings of p, T and e must be taken by standard instruments to establish the absolute value of refractive index at one or two points on the record. The speed of response of the radio refractometer is about the same as that of the ultra rapid thermometer.

No entirely satisfactory instruments have yet been developed to measure cloud and raindrop size distribution and liquid water content. On the Hastings a magnesium oxide impactor is used to measure cloud droplet size distribution. A slide coated with magnesium oxide is exposed for about 1/100 of a second and the cloud droplets make impressions in the oxide film. These are photographed under a microscope after the flight. A chronotron is used to measure the time of exposure. For raindrops the impressions are made in aluminium foil. A hot wire liquid water content meter is also fitted. This measures the reduction in resistance of a hot nickel wire when rain or cloud drops impinge on it. The accuracy of the calibrations of the magnesium oxide impactor and the hot wire water content meter is in doubt and the calibrations are at present under investigation.

Crown copyright

PLATE I—MAJOR K. J. GROVES PRESENTING THE MEMORIAL PRIZE FOR METEOROLOGY TO MR. T. H. KIRK

See page 62

Crown copyright

PLATE II—THE HASTINGS AIRCRAFT OF THE METEOROLOGICAL RESEARCH FLIGHT FLYING OFF THE ISLE OF WIGHT

The cloud warning radar is in the pod under the nose. See page 47

PLATE III—THE STARBOARD SIDE OF THE HASTINGS OF THE METEOROLOGICAL RESEARCH FLIGHT

1. Experimental power supplies switch panel. 2. Radio and navigational equipment. 3. Radio power supplies switch panel. 4. Vertical current measuring equipment. 5. A.c. power supplies.

See page 47.

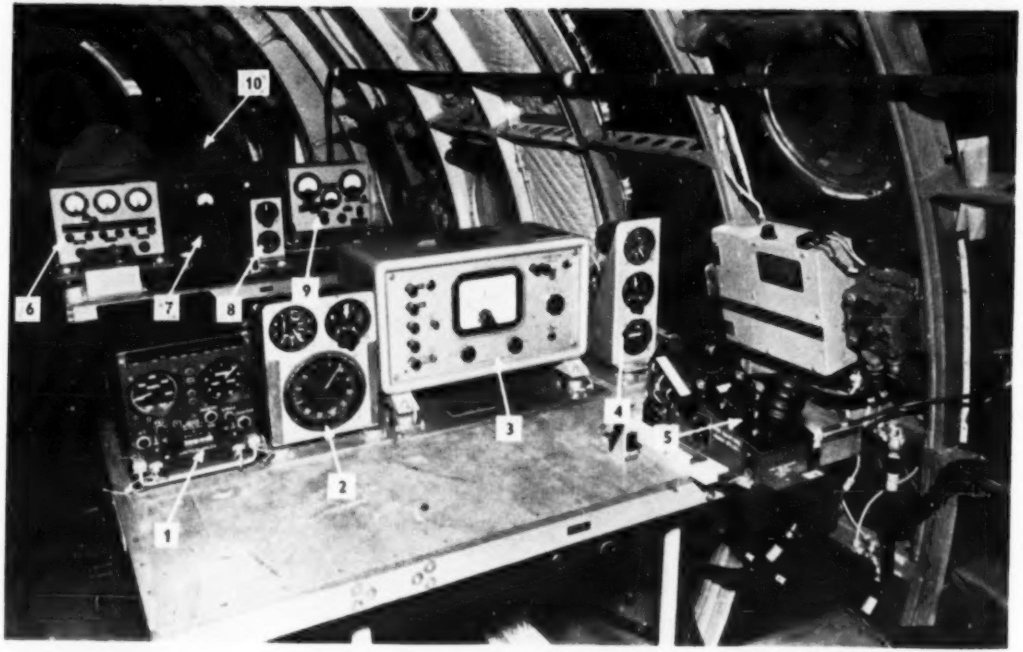


PLATE IV—THE PORT SIDE OF THE HASTINGS AIRCRAFT OF THE METEOROLOGICAL RESEARCH FLIGHT

1. Doppler radar control unit. 2. Airspeed indicator, altimeter, and compass repeater. 3. Chronotron. 4. Airspeed indicator, altimeter and self balancing bridge indicator. 5. Hygrometer and balanced-bridge temperature indicator. 6. Ultra rapid thermometer amplifiers. 7. Radio refractometer. 8. Altimeter and airspeed indicator. 9. Hot wire water content meter. 10. Multi-channel galvanometer recorder. See page 47.

To face p. 49

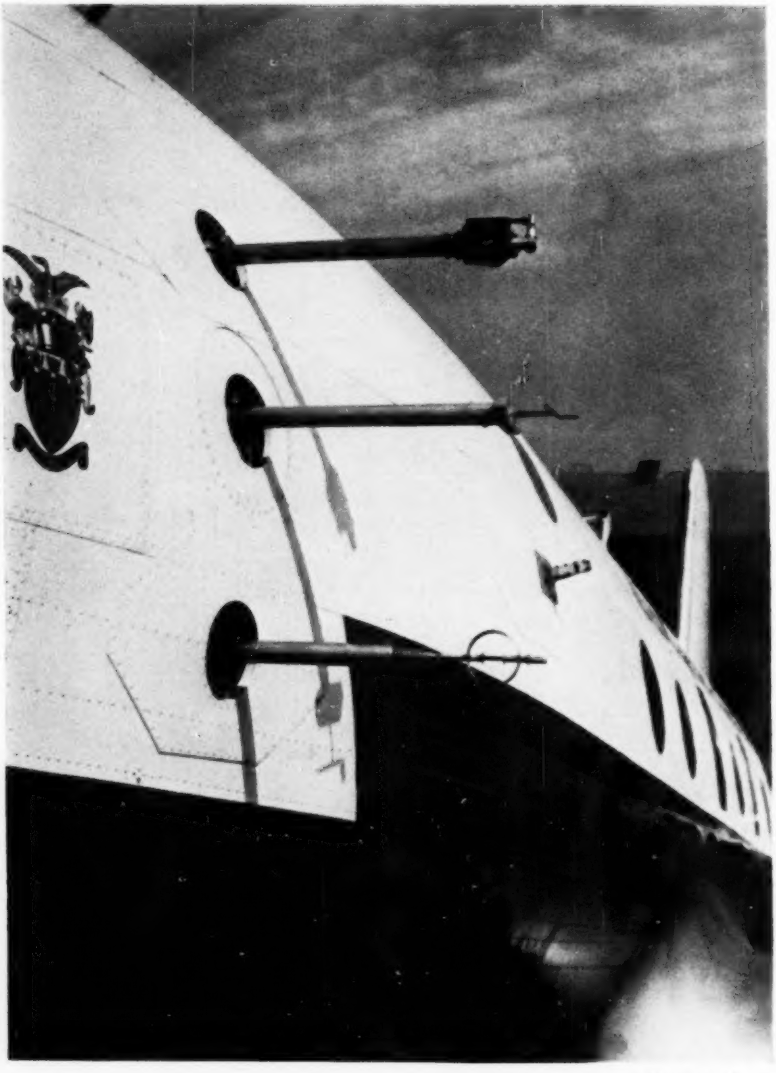


PLATE V—EXTERNAL VIEW OF INSTRUMENT EXPOSURE POSITION

From top to bottom, radio refractometer cavity, angle of incidence wind vane, and magnesium oxide impactor. See page 47.

Chloride particles can be collected on a slide coated with gelatin impregnated with silver nitrate solution. The diameter of the stain caused by the reaction of the chloride with the nitrate and the subsequent reduction of the silver chloride to metallic silver enables estimates to be made of the masses of the chloride particles.

For detection of particles of precipitation size a 3-cm radar is now available.

Winds can be measured using a Doppler radar. This displays instantaneous readings of ground speed, drift and heading, and if simultaneous readings of airspeed are taken the wind can be calculated. The error in winds obtained by this method is more than 5 knots. Greater accuracy can be obtained by flying for a short time and comparing changes in ground position and air position. A ground position indicator (which is operated by the Doppler radar) and an air position indicator are fitted for this purpose. To obtain the highest possible accuracy the output from the ground position indicator is fed into repeater boxes which indicate changes in ground position to the nearest 0.02 nautical miles in the north and south direction, and the output from the air position indicator is fed into a wind finding attachment with a similar accuracy. With a time interval of one minute, wind errors are then reduced to about 2 knots.

Vertical air currents of a scale encountered in cumulus clouds are obtained by measuring (i) the vertical velocity of the aircraft relative to the ground (by integration of an accelerometer) and (ii) the vertical velocity of the air relative to the aircraft, and adding (i) and (ii) to obtain the vertical velocity of tne air relative to the ground. The component (ii) is obtained by a wind vane which measures the angle of incidence of the air relative to a fixed axis on the aircraft, a pitch gyro which measures the angle of this axis relative to the ground (this angle changes due to pitching of the aircraft), and the true airspeed of the aircraft. Small corrections have to be applied to some of the measurements for angle of roll and rate of pitch. Many measurements have therefore to be made at a very high frequency to obtain vertical currents by this method.

All instruments are either read by an observer in the air or are recorded on a multi-channel galvanometer recorder. The latter is used if readings are required at a high frequency. At present the following observations can be recorded on film moving at speeds up to 15 cm/sec:

Time (in seconds)	Liquid water content
Airspeed	Pitch angle
Temperature (standard element)	Roll angle
Ultra rapid temperature	Rate of pitch (or roll)
Radio refractive index	Vertical acceleration of aircraft
	Angle of incidence of wind

ICAO (International Civil Aviation Organization) height.

An example of a record of a flight in turbulent conditions with some of these instruments in operation is shown in Figure 1.

Layout of equipment.—The officer in charge of the flight has a good view in the forward direction. He has control of the 3-cm radar equipment and can therefore tell whether a cloud ahead contains precipitation particles. He also has a thermometer on which he can read air temperature.

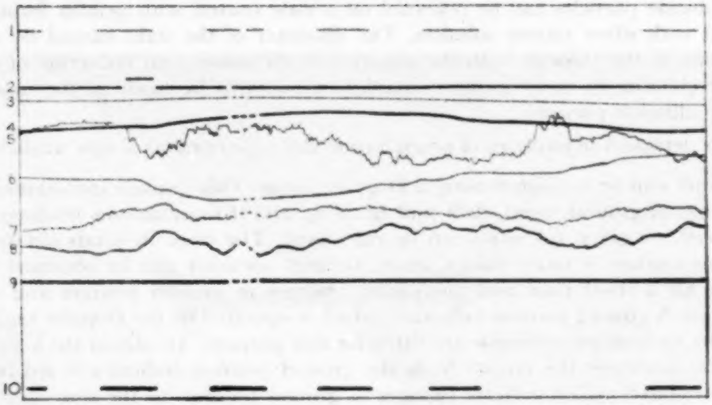


FIGURE I—AN EXAMPLE OF A RECORD OF A FLIGHT IN TURBULENT CONDITIONS

1. Half-second time marks; 2. Event marker; 3. Coarse airspeed; 4. Sensitive height; 5. Wind vane; 6. Sensitive airspeed 7. Rate of pitch; 8. Vertical accelerometer; 9. Coarse height; 10. Half-second time marks.

On the first table behind the ramps there are seats for two observers. At one position indicators of ground speed, airspeed, drift heading and height are available. These observations are made when spot winds are required. At the other position temperature, frost-point, airspeed and height can be read. On this table there is also the chronotron for measuring the time of exposure of the magnesium oxide slides in cloud.

At the next table there is the radio refractometer, ultra rapid thermometer and hot wire water content meter, and on the third table there is the recorder and the ground position repeater box. Two other tables are available, one of which has the self balancing bridge and the other has the signaller's equipment. There is ample space on these tables for future developments.

On each table and at the officer-in-charge's position there are switches for putting event marks on the recorder to indicate the occurrence of something of interest, e.g. entry into cloud, passing through haze top, etc.

The layout of the equipment has been arranged to reduce to a minimum the number of observers carried on each experimental flight. The number required varies from one to four depending on the project.

Navigational aids.—The Hastings is now equipped with most of the latest navigational aids and can be operated in any part of the world. A detachment to El Adem has already been made and further overseas flights are being considered.

Projects.—There are many projects assigned to MRF on the research programme of the Meteorological Research Committee, but only a few can be worked on at any one time. At present a large effort is being put into the

instrumentation. The equipment for vertical current measurement is being improved and consideration is being given to recording the output of all instruments in digital form on magnetic tape in a form suitable for feeding directly into a *Mercury* computer. The very tedious work of reading film records will then be eliminated. A study of the accuracy of wind measurement is being made to see if the divergence of wind within a closed area can be measured with sufficient accuracy to deduce from it vertical currents on a much larger horizontal scale than that of an individual cumulus cloud. Calibration of the cloud-physics instruments is proving to be a very difficult problem, but it is hoped that progress will be made using a spinning disk to generate a cloud of drops of known size and projecting through it a magnesium oxide coated slide mounted on a bullet fired from an air gun designed by the Royal Aircraft Establishment.

Concurrently with this instrumental work (which itself requires a large amount of flying) a number of other flying projects are in progress using the Hastings. The instruments with high response speeds are being used in a study of convection and the recent detachment to El Adem combined a study of convection over the desert with some measurements in sea-breeze conditions. Flights are being made in frontal rain using the aluminium foil impactor to study the variation of precipitation intensity with height.

Conclusions.—There is no doubt that experimental work in the Hastings is greatly facilitated by its refitting and re-equipment. All the modifications to the aircraft were done by the Experimental Aircraft Services Department of the Royal Aircraft Establishment and we are grateful to them for the speed and efficiency with which they planned and executed the project.

551.501.5:551.509.325:551.575.1

A DIAGRAM TO ASSESS THE TIME OF FOG CLEARANCE

By J. A. BARTHRAM

Introduction.—Radiation fog is normally expected to clear when insolation has caused the temperature to rise sufficiently to give at least a saturated lapse rate from the surface to the fog top. To forecast the time when the required surface temperature (the 'clearance temperature') will be reached, an estimate has to be made of the insolation necessary to raise the temperature of the air to the required level, plus that needed to warm and evaporate the water droplets of the fog. Kennington[1] has shown that the extra insolation required for the water content can be taken into account by increasing the insolation needed for air by a simple factor. This factor is dependent only on the dawn temperature and the clearance temperature. He has also given an estimate of the total insolation received at the top of a fog and available for dispersing it. The present paper puts his results in a form readily usable by a forecaster, and includes a set of diagrams from which the fog clearance time can be quickly assessed.

Basis of the diagram.—Figure 1 shows a frequent type of ascent curve at the end of a night during which radiation fog has formed. Taking the surface temperature at dawn as T_1, the clearance temperature as T_2, and the fog top as A, then for practical purposes the heat required to raise the temperature of the air from T_1 to T_2 is proportional to the area of the triangle T_1 T_2 A.

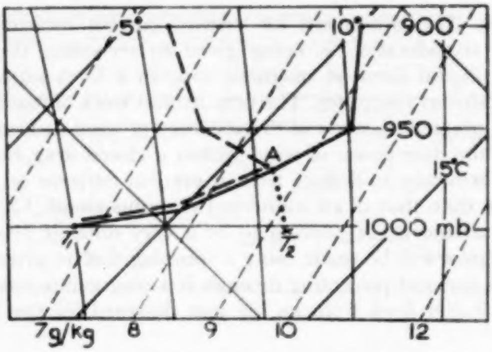


FIGURE 1—ASCENT CURVE ON NIGHT OF FOG

——— dry-bulb temperature, – – – dew-point temperature, T_1 dawn temperature, T_2 fog clearance temperature, 'A' indicates fog top.

On the large-scale inset tephigram of Meteorological Office Form 2810A (1956 edition), at pressures and temperatures likely to be experienced in radiation fog, 1°C = 0.7 cm, 10 mb = 0.28 cm, and 1 cm² represents an energy of 12.5 gm cal/cm². Thus the insolation, H, required to raise the temperature of air from T_1 to T_2 is given by

$$H = \tfrac{1}{2}\,(T_2 - T_1) \times 0.7 \times D \times 0.028 \times 12.5 \text{ gm cal/cm}^2$$

where D is the depth of fog in mb.

Kennington[1] showed that in order to warm and evaporate the liquid water, the insolation H must be increased by a factor F given by

$$F = \frac{T_1 + T_2}{60} + \frac{2}{3}$$

where the temperatures are in Fahrenheit. Figure 2 was drawn to obtain F when temperatures are in degrees Fahrenheit or Celsius.

FIGURE 2—GRAPH TO DETERMINE FACTOR F USING FAHRENHEIT OR CELSIUS SCALES

Figure 3 shows selected lines of constant values of H for temperature differences up to 10°C and fog depths up to 60 mb.

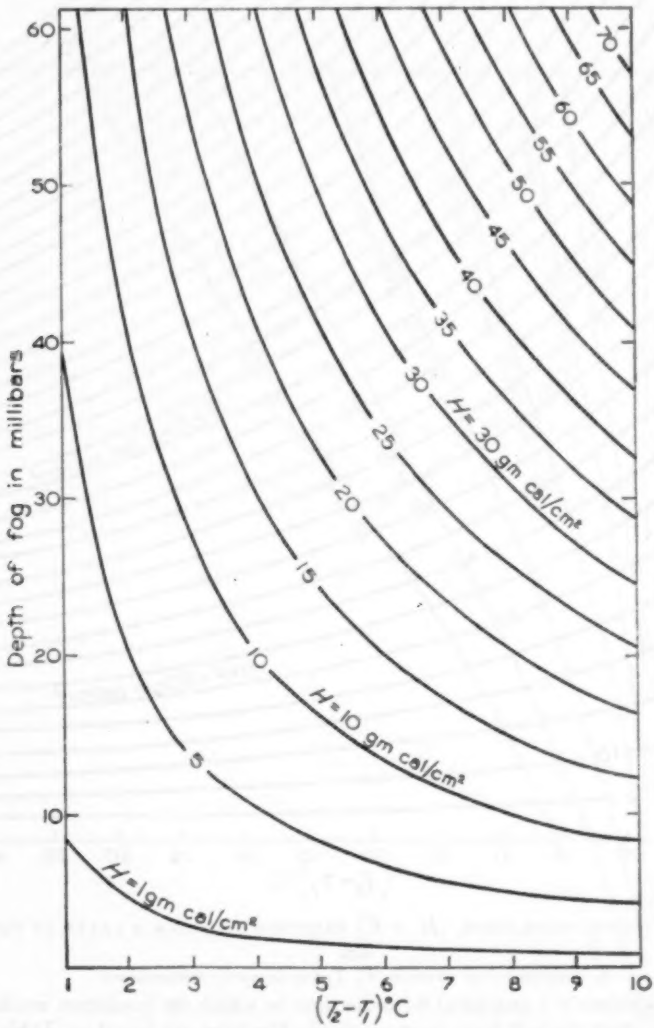


FIGURE 3—INSOLATION, H, REQUIRED TO WARM A LAYER OF DRY AIR

T_1 temperature in °C at dawn, T_2 fog clearance temperature.

The insolation values of Figure 3 were then multiplied by the values of F obtained from Figure 2, thereby finding the total insolation required to disperse the fog. Selected lines of constant values of this total insolation were drawn to produce Figure 4.

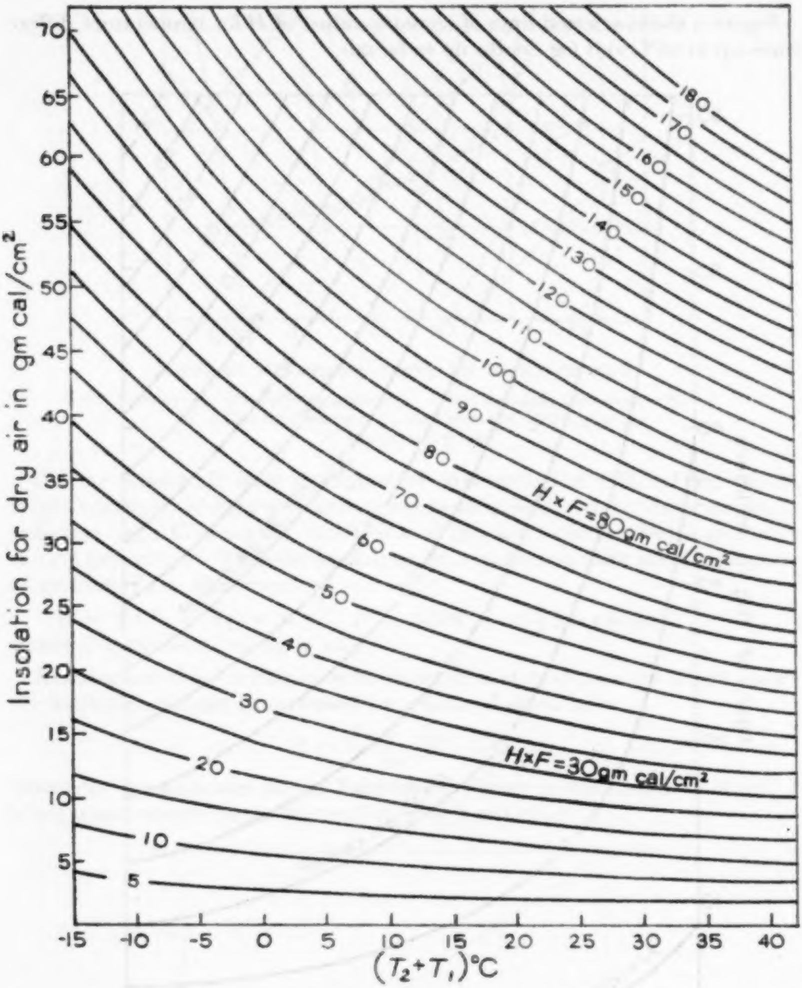


FIGURE 4—TOTAL INSOLATION, $(H \times F)$ REQUIRED TO WARM A LAYER OF FOGGY AIR

T_1 temperature at dawn in °C, T_2 fog clearance temperature.

Figure 5 shows in a graphical form the time by which the insolation available to disperse thick fog will have been received. The lines are based on Table III of Kennington's paper,[1] on the assumption that the figures given there refer to the middle of the month at the Greenwich meridian. Months have been grouped where this did not produce an error of more than 15 minutes in the time by which a given insolation was received. For a thin fog Kennington suggests that the insolation available for dispersal of fog is increased by half. No definition of a thin fog was given by Kennington, but experience has pointed to a visibility of not less than 600 yards.

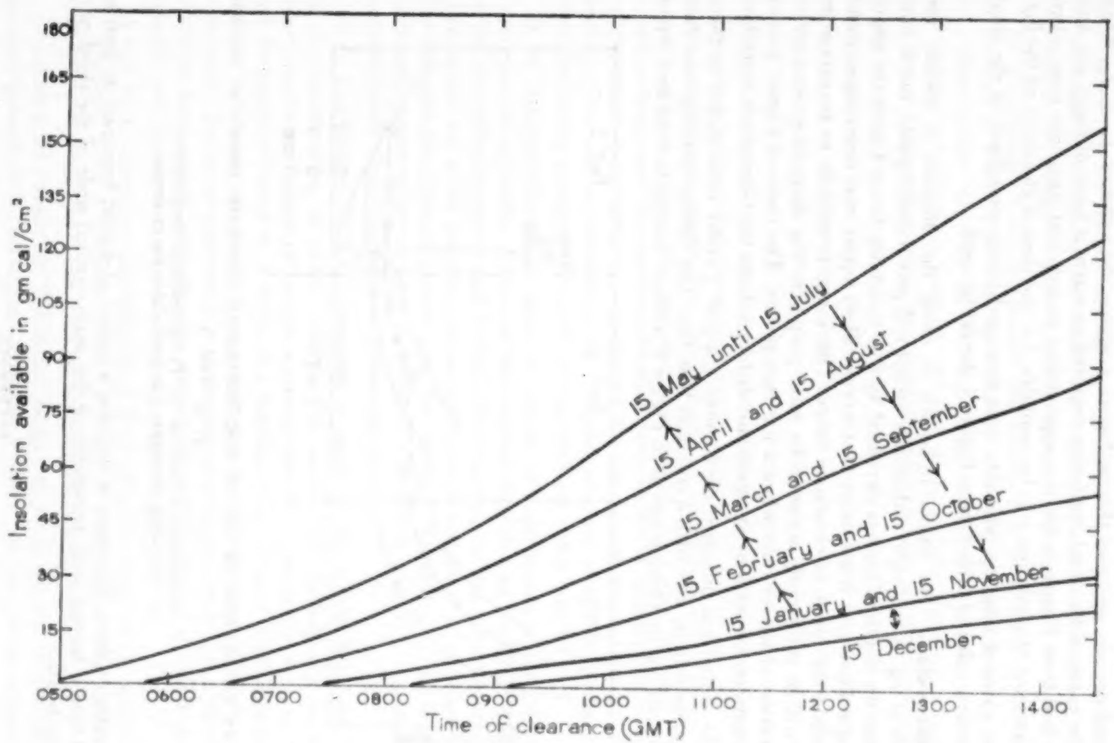


FIGURE 5—INSOLATION AVAILABLE BY VARIOUS TIMES

Method of use of the fog clearance diagram.—Firstly a forecast is required of the clearance temperature (T_2°C) by any preferred method, also the value of the dawn temperature (T_1°C) and the fog depth in millibars must be known or estimated. On Figure 3 plot the temperature difference $T_2 - T_1$ against the depth of fog. Read off the value of the insolation required to warm a layer of dry air, and plot this on Figure 4 against the value of $T_1 + T_2$. Read off the value of the total insolation required to warm a layer of foggy air, and then find from Figure 5, for the appropriate month and date, the time when this amount of insolation will be available, i.e. the time of clearance of the fog.

For cases of thin fog (visibility over 600 yards) only two-thirds of the total insolation value obtained from Figure 3 should be used.

Discussion.—The major unknown in using the diagram is usually the depth of fog. A midnight radiosonde ascent will give a useful guide, but it may be that the depth of fog has increased by 5 to 15 mb by dawn. Unless the depth of fog is known, it is probably best to take likely upper and lower figures and calculate the range of clearance times. This range is unlikely to be excessive, and will be sufficiently accurate for most purposes. The diagram gives a useful indication of winter days when a fog may persist. The times of Figure 5 must be amended for stations at significant distances from the Greenwich meridian.

The author has mounted the Figures 3, 4 and 5 under clear plastic as three diagrams side by side with a common base line. The various readings can then be traced out by chinagraph as in Figure 6 without having to read and replot

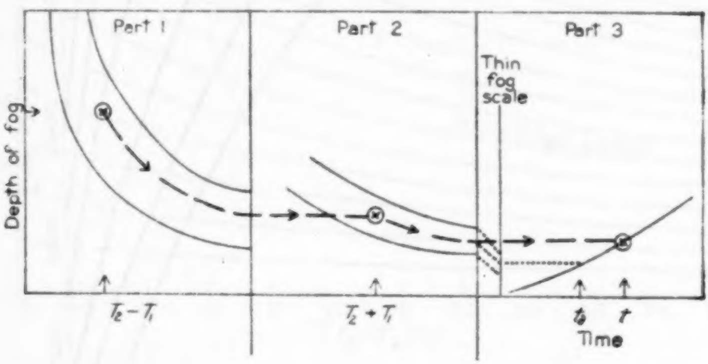


FIGURE 6—METHOD OF USE OF FOG CLEARANCE DIAGRAMS SHOWN IN FIGURES 3, 4, AND 5

T_1 temperature at dawn in °C, T_2 fog clearance temperature, t is time of fog clearance, t_a is time of thin fog clearance.

insolation values. For cases of thin fog a system of dotted lines can be used to lead into a special scale two-thirds of the main vertical scale of the third part of the figure.

REFERENCE

1. KENNINGTON, C. J.; An approach to the problem of the forecasting of fog clearance. *Met. Mag. London*, **90**, 1961, p. 70.

551.574.1:061.3

THE FIFTH INTERNATIONAL SYMPOSIUM ON CONDENSATION NUCLEI

By J. B. STEWART, B.Sc., D.I.C.

The symposium took place from 13 to 17 May 1963. The first half, comprising three sessions on ice nuclei, was held at Clermont-Ferrand and the second, of five sessions on condensation nuclei, at Toulouse, at the invitation of the Universities of Clermont-Ferrand and Toulouse respectively.

The programme of the symposium and abstracts of the papers appeared in the Journal de Recherches Atmosphériques,[1] (this journal replaces the Bulletin de l'Observatoire du Puy de Dôme). Full papers are published in the next edition of the same journal. Of the thirty papers presented, about a third were of direct interest to the cloud physicist and are summarized here.

The first lecture was given by V. J. Schaefer (U.S.A.) who used slides and a film to describe some of the studies and observations made in the geyser and hot springs area of Yellowstone Park.[2] Since the air in this area contains very few nuclei—about 50 particles per cubic centimetre—it can be used as a natural laboratory to study conditions of high supersaturation and supercooling. For example the film showed the dramatic effect of burning pine cones to provide a source of condensation nuclei upwind of one of the hot pools. When nuclei were supplied, a thick plume of condensed water drops was formed, whereas before there had been only a slight haze over the pool. Particularly striking were the photographs which were shown of optical phenomena—haloes, mock suns, arcs etc.—produced by ice clouds formed by artificial seeding. This was in contrast to the complete absence of optical phenomena when ice clouds occurred naturally at temperatures below $-40°C$.

H. W. Georgii (Germany) gave the results of experiments of the effects of trace gases on ice nuclei. He found that sulphur dioxide had a negligible effect on the ice nucleating power and similarly for ammonia, unless the concentration of ammonia was much greater than occurs in the atmosphere. In the discussion that followed Dr. Georgii agreed with Dr. Soulage (France) that the lowered nucleating power of ice nuclei in polluted air was due to coagulation with other particles rather than poisoning by industrial gases.

H. R. Pruppacher (U.S.A.) presented a paper on the effects of soluble salts on the supercooling of water droplets. To resolve the discrepancy between theory and experiments of earlier workers, further experiments were carried out. Pruppacher found that drops of a solution with a concentration of more than 10^{-2} mole per litre had a lower mean freezing temperature than drops of pure water. He has also shown that in the previous experiments, large numbers of nuclei were added with the salt and so the freezing-point of the drops of solution was higher than that of the pure water drops.

A film by R. Serpolay and Mlle M.-J. Toye (France) showed the growth of ice 'whiskers' from a nucleus, viewed through a microscope. The 'whiskers' were less than 10 μ thick, but grew to about a millimetre long.

J. A. Day read a paper by N. Fukuta (Japan) and B. J. Mason (U.K.) on the epitaxial growth of ice on organic crystals. They found that of the substances tested, the most effective were the stearoids. On several of these, ice crystals would grow at temperatures only one or two degrees below $0°C$. The nucleating

power of these compounds is not caused by similarity of their crystal structure to that of ice, but by the presence and arrangement of certain groups in their molecules, which form bonds with the water molecules and so facilitate the phase change.

J. Podzimek (Czechoslovakia) presented calculations which showed that water-vapour pressure gradients near condensing droplets are sufficiently great to make diffusiophoresis—transport down the water-vapour pressure gradient—important in the capture of insoluble particles by condensing cloud drops. This result is in conflict with recent work reported by Goldsmith.[3]

J. P. Lodge (U.S.A.) described further work that he and H. A. Bravo (U.S.A.) have carried out using Millipore filters to measure ice nucleus concentrations.[4] They used this method to test organic materials such as those studied by Fukuta and Mason. For inorganic materials and natural aerosols, the Millipore filter method agrees very well with other methods, but the agreement is poor for organic substances. Thus for cholesterol the threshold temperature given by the Millipore filter method was -14°C, compared to -1°C as found by Fukuta and Mason. Lodge and Bravo have also collected snow flakes on Millipore filters, which were then warmed to evaporate the snow flakes and the residues tested to find the temperature of ice formation. With natural snow it was found that none of the residues was active at -15°C, whereas with snow formed by seeding with silver iodide, every residue was active at -15°C. Thus it may be possible, the authors suggest, to detect silver iodide in ice crystals.

The rest of the symposium dealt with condensation nuclei.

S. Twomey (U.S.A.) described measurements of the concentration of particles on which drops form in natural clouds. It is known that only a small number of the available nuclei grow into cloud droplets and that the supersaturation is very rarely greater than one per cent. Also it has been shown that to grow a drop of 5 μ radius takes some seconds at one per cent supersaturation and about 40 seconds at 0.1 per cent supersaturation. To be able to measure the concentration of nuclei forming drops in natural clouds, Twomey used a thermal diffusion chamber to give steady supersaturations at values down to 0.1 per cent. His results, obtained with this apparatus suggest, that the major source of the nuclei effective in cloud formation is the continents, but the nuclei are not man-made. He found little difference between the concentrations of such nuclei in the air at the surface in Washington, D.C. and at 10,000 feet.

Mlle M. Deloncle (France) described observations of particles up to 10 μ diameter in a fog near Paris, when the relative humidity was as low as 70 per cent. She suggested that this was caused by the presence of sulphur dioxide and sulphur trioxide.

J. A. Day (U.S.A.) described his experiments and results on the formation of small drops by the rupture of air-bubble films. By allowing the bubble to burst in a highly supersaturated environment, the droplets grew sufficiently to be photographed with a cine-camera and counted. He found that the number of droplets increased as the bubble diameter increased—this disagrees with Mason's results,[5] which suggested that the number of droplets was independent of the bubble diameter. Day found that in distilled water, a bubble of 2.2 mm diameter gave about 30 droplets, and in three per cent saline solution about 100 droplets.

D. C. Blanchard (U.S.A.) described some of his experiments into the origin of condensation nuclei. He has shown that no nuclei were produced when an air-borne drop of sea water crystallizes. In experiments on the rupture of air-bubble films, Blanchard found that the number of droplets produced was comparable with that found by Day and also was dependent on the diameter of the bursting bubble. However, if there was surface-active contamination present, no droplets were formed when the bubble burst at the surface.

On the last day of the symposium the participants were taken to the Lannemezan plain—75 miles west-south-west of Toulouse—to see the Météotron in operation. The Météotron consists of a large number of oil burners, which consume a ton of fuel per minute, arranged in the shape of a hexagon. When the Météotron is working the heat from the burners produces an artificial thermal, which is made visible by the smoke carried up with it. Unfortunately the demonstration was not wholly successful, partly because the meteorological conditions were unfavourable—low humidity at the surface, and a 6/8 layer of stratocumulus with its base at about 6000 ft—and partly because the equipment was not fully serviceable. It was impossible to say whether the Météotron produced any cloud.

The general impression of the symposium was one of a useful exchange of ideas in a particularly pleasant and informal atmosphere, owing not a little to the excellent arrangements made by Professor H. Dessens and his colleagues. Much of the benefit of the symposium came from discussions held after the formal proceedings were over, both in the conference hall and out of it.

REFERENCES

1. Clermont-Ferrand, l'Observatoire du Puy de Dôme. V^e Symposium International sur les Noyaux de Condensation; Programme. *J. Rech. Atmosph., Clermont-Ferrand*, **1**, 1963, p. 46.
2. GOLDSMITH, P., DELAFIELD, H. J. and COX, L. C.; The role of diffusiophoresis in the scavenging of radioactive particles from the atmosphere. *Quart. J. R. met. Soc., London*, **89**, 1963, p. 43.
3. SCHAEFER, V. J.; Condensed water in the free atmosphere in air colder than −40°C. *J. appl. Met., Lancaster, Pa.*, **1**, 1962, p. 481.
4. LODGE, J. P. and BRAVO, H. A.; An improved technique for the determination of freezing nuclei concentrations. *Bull. Obs. du Puy de Dôme, Clermont-Ferrand*, Série 2, 10^e Année, 1962, p. 81.
5. MASON, B. J.; The oceans as source of cloud-forming nuclei. *Geofis. pur. appl., Milan*, **36**, 1957, p. 148.

REVIEWS

Mean monthly temperature and salinity of the surface layer of the North Sea and adjacent waters from 1905 *to* 1954, prepared and published by the Conseil Permanent International pour l'Exploration de la Mer, Service Hydrographique, Charlottenlund Slot, Denmark, preface by G. Dietrich. 14½in. × 13¾in., *illus.*, pp. 318, 1962. Price: DK 45.

This beautifully printed and produced atlas gives monthly average maps of sea surface temperature (isotherms at intervals of half a degree Celsius), for each month of the year for the 50-year period 1905–54 for the waters surrounding the British Isles between 47½ and 63°N, 11°E and 21°W, including inshore waters. There are corresponding maps of salinity for each month—the isopleth interval is not uniform but all lines are clearly labelled. It is the first time that maps of both items over this whole region have been published for the same period of years—a small but important detail which one should be scrupulous

about because of the well known warming trend during much of the last half-century. It was already known that water temperatures in the English Channel averaged 0.6°C higher in 1928–51 than in 1903–27.

Sources of data used include British lightships and coastal stations, the lightships of other neighbouring countries, Danish, Dutch and German merchant vessels and various research ship observations from the archives of the International Council for the Exploration of the Sea. The observations from research ships were compared with those from merchant vessels but the comparison suggested no noteworthy systematic discrepancies between the work of the two classes of vessel. All the observations were made at less than 5 metres depth.

The $1\frac{1}{3}$ million temperature observations and 400,000 odd salinity observations available were unevenly divided over the area and in time, values for the years 1940–45 being particularly scarce. This meant that considerable skill had to be used in arriving at the isopleth analysis, when covering sparse areas, where the few observations available might have been made on unrepresentative occasions. In order to avoid any possibility of the analyst's personal bias misleading the user it was decided to publish not only the maps, but also tables giving monthly mean values and the number of available observations in every month of every year for each of 293 sea areas. This additional material makes up the main weight of the book. It is an addition of very great value for a number of purposes besides the one stated.

Ever since the publication of monthly mean values year by year over long periods of years for land stations all over the world in *World Weather Records* (the original volume being published by the Smithsonian Institution in 1927,[1] the latest volume (observations to 1950) by the U.S. Weather Bureau in 1959[2]), meteorologists—concerned with long-term variations and trends, or with the interactions between atmosphere and ocean—have wished to see similar long series of values of ocean surface temperature, at least for a few positions in the ocean representative of the main water bodies. There has been a plan in the Meteorological Office for some time past to produce such series for a few particular points in the world's oceans for use in research on climatic variations and long-range forecasting. Long-range weather forecasters anywhere in Europe, seeking to identify analogous situations in past years, are sure to make frequent reference to the tables now provided in this atlas.

The 293 areas for which mean values are given month by month over the 50 years comprise 46 four-degree "squares", 114 one-degree "squares", 71 quarter-degree "squares" and a remainder of intermediate sizes. Unfortunately it is only a minority of these areas for which the series are anything like complete, chiefly "squares" along the main shipping routes to the south-west and west about latitudes 50 and 57°N and the Faeroes–Iceland route. This distribution brings home the sad lack in our arrangements for collecting information from ships in the central North Sea and indeed in many other areas between the Western Approaches and the ports. Some important areas could perhaps be covered some day by automatic floating weather stations.

Even a cursory examination of the maps brings out many points which are not generally familiar. The warmest waters at the time of the annual maximum in August are along the Dutch and German coasts and (though this is not

specifically shown) in the inner reaches of Oslofjord. On average the coasts of Brittany and Cornwall are 2°C cooler. The warmest waters in summer near this country are off the Thames and Essex, approached by those off Sussex and Hampshire, in the Bristol Channel and Cardigan Bay and bordering the Lancashire coasts. The coldest waters in February are in the coastal shallows and show an obvious relation to the regions of low salinity—Oslofjord, the German Bight, the Dutch coast, the Wash, the Lancashire coast and innermost Moray Firth (in ascending order of average temperature). Seasonal warming and cooling is particularly rapid in some of these areas. The tables of monthly values will facilitate the reckoning of standard deviations which also promise to hold some interesting lessons. Variability from year to year seems higher in the North Sea than in the broad waters of the North Atlantic drift, but appears to be high in the prominent tongue of cold water which approaches the Faeroe Islands from the north. Evidently the east Iceland arm of the Greenland current, with which this tongue is presumably connected, is one of the most variable features near enough home to effect British weather.

The applications of this very practical and yet very scientifically produced work clearly range from fisheries and marine biology to tourism and bathing, as well as to the growing meteorological effort on long-range weather forecasting and climatic trends. This atlas should find a place in a number of commercial and industrial offices as well as in scientific laboratories. It should also serve as a model for further enterprises.

H. H. LAMB

REFERENCES

1. Washington, Smithsonian Institution. World weather records. *Smithson. misc. Coll., Washington D.C.*, **79**, 1927.
2. Washington, U.S. Department of Commerce Weather Bureau. World weather records 1941–50. U.S. Weather Bureau, Washington D.C., 1959.

Boletin de estadistica meteorologica e hidrologica, No. 1 *and* 2, Ministerio de Agricultura, Servicio de Agrometeorologia e Hidrologia. 8½in. × 11in., pp. 40, Pacific Press, S.A., Av. Brasil 537, Lima, Peru, 1962.

These two publications are the first of a series which will eventually give Peruvian meteorological and hydrological data, grouped according to river basins. It will be interesting to see how quickly the whole country is covered, and how data for succeeding years can be added to the present publications. In some cases the layout seems wasteful unless a standard form is deemed essential for the future. No information is given concerning how the observations are made—particularly important in the case of evaporation data. The plan seems a promising one although it is difficult to judge on the basis of the first publications in the series. (Statistics are now published for at least 19 river basins.)

A. BLEASDALE

HONOUR

The following award was announced in the New Year Honours List, 1964:

M.B.E.

J. Bell, B.Sc., Senior Experimental Officer, Meteorological Office, Bracknell.

AWARDS

L. G. Groves Memorial Prizes and Awards

The presentation of the L. G. Groves Memorial Prizes and Awards for 1963 was made by Major K. J. Groves in the Air Historic Room at Air Ministry, Whitehall, on 15 November 1963. These annual awards were instituted by Major and Mrs. K. J. Groves in memory of their son Sergeant L. G. Groves, RAFVR, who was killed on a meteorological sortie in 1945.

The Memorial Prize for Aircraft Safety was awarded to Flight Lieutenant A. W. Price of RAF Coningsby, who perfected a device which enables survivors from crashed aircraft, on land or sea, to be spotted on the radar of searching aircraft or ships at long range, and which can be carried in dinghy survival packs. It is called 'R.I.T.A.' (Reflecting Indicator for Aircrew). Flight Lieutenant Price donated the greater part of his award to charity.

Mr. T. H. Kirk of the Meteorological Office, Bracknell, received the Memorial Prize for Meteorology, for his work on duties in Malta, and for his 'exceptional interest' in the scientific problems of weather forecasting. Among scientific papers he has had published are detailed reports on a tornado, low-level turbulence, pressure jumps, and other features of climatic conditions in Malta. (See Plate I.)

The Air Meteorological Observers' Award, presented to a member of aircrew employed on meteorological observer or other flying duties relating to meteorology for meritorious work and devotion to duty, was won by Flight Lieutenant D. H. Gannon, of RAF Farnborough. He has for four years flown as a navigator on meteorological research flights, showing the highest efficiency and completing 350 sorties in more than 900 hours flying in Canberra, Hastings and Varsity aircraft. Flight Lieutenant Gannon was navigator in the RAF Canberra which won the 1953 England to New Zealand Air Race.

Finally the Second Memorial Award, for meritorious work in any of the fields covered by the other three prizes, was won by Chief Technician J. Mulholland, of RAF Binbrook. He designed a portable set for making regular and careful pre-flight checks at forward landing strips to ensure the correct and safe operation of the complex flying clothing and equipment used in the RAF.

NOTES AND NEWS

Conference on Atmospheric Radiation, 1964

The International Radiation Commission of the International Association of Meteorology and Atmospheric Physics of the International Union of Geodesy and Geophysics is having a conference at Leningrad, from 10–15 August 1964. There will be both invited and contributed papers on a wide variety of topics of current interest in the field of Atmospheric Radiation.

Further information may be obtained from: Professor J. London, Department of Astrophysics and the Atmospheric Sciences, University of Colorado, Boulder, Colorado, U.S.A., and Professor M. I. Budyko, The Main Geophysical Laboratory, M. Spasskoya 7, Leningrad K–18, U.S.S.R.

Conference on Radio Meteorology, 1964

The Inter Union Committee on Radio Meteorology (of the International Scientific Radio Union and the International Union of Geodesy and Geophysics) is arranging a conference at Boulder, Colorado from 14–18 September 1964. The symposium will cover all aspects of Radio Meteorology and will incorporate the eleventh Weather Radar Conference sponsored by the American Meteorological Society.

The organizing committee would like to hear now from all those interested in attending and participating in the conference. Contributed papers will be reproduced, and then distributed a month or more before the conference to allow the necessary thorough reading by all participants.

Correspondence should be addressed to Mr. J. W. Herbstreit, Program Committee, 1964 World Conference on Radio Meteorology, Central Radio Propagation Laboratory, National Bureau of Standards, Boulder, Colorado, U.S.A.

CORRIGENDA

Meteorological Magazine. October, 1963, between pages 302, 303. Caption to Plate IV should read 'The aircraft, based at RAF Syerston, was flying at 7000 feet in cumulus-type cloud above Cottesmore.'

Meteorological Magazine, October 1963, page 339, line 28: for 69°F read 69–73°F.

TWO NEW DECCA WEATHER RADARS

THE DECCA TYPE 42

A general purpose radar system for continuous weather watch.

Simple to install

Straightforward to operate

Low capital and running costs

The latest general purpose Decca Weather Radar, Type 42, is a robust equipment with PPI presentation, designed for extremely simple operation and maintenance. The 80 kW transmitter provides ample performance for detecting and tracking precipitation to a range of 400 km, depending on the height of storm heads. The aerial tilt facility, remotely controlled from -2° to +28°, enables the height to which precipitation extends to be estimated.

Type 42 can be used with the Decca Radargraph system for transmitting radar information over narrow bandwidth (3 kc/s) channels with visible and automatic recording at any desired location.

Frequency: In the band 9300 to 9500 Mc/s

Aerial: Horizontal beam 0.8°, vertical beam 2.8°, tilt -2° to +28°, rotation 10 r.p.m.

Pulse: Peak power 80 kW, pulse length 2 or 0.5μ sec, PRF 250 p.p.s.

Displays: 12 inch PPI, Radargraph (optional)

THE DECCA TYPE 43

A Weather Radar for advanced operational and research roles

Versatile aerial system

PPI and RHI presentation

Direct CAPPI recording

Type 43 is the most advanced of the Decca 3 cm Weather Radars and incorporates a new aerial system giving a very narrow beamwidth in the vertical plane. This aerial may be rotated continuously for PPI presentation to show the position, extent and movement of precipitation areas; nodded in the vertical plane to examine the structure of weather returns using RHI presentation; or programmed in elevation during continuous rotation to give direct, visible CAPPI (constant altitude PPI) recordings for four selected levels simultaneously.

Frequency: In the band 9300 to 9500 Mc/s

Aerial: Vertical beam 0.8°, Horizontal beam 2.8°, tilt 0° to +35°, rotation 10 or 20 r.p.m.

Pulse: Peak power 80 kW, pulse length 2 or 0.5μ sec, PRF 250 p.p.s.

Displays: 12 inch PPI, 12 inch RHI (optional), Radargraph (optional), Cappigraph (optional).

DECCA RADAR

DECCA RADAR LIMITED LONDON ENGLAND

DR 3469

THE METEOROLOGICAL MAGAZINE

VOL. 93 NO. 1099 FEBRUARY 1964

CONTENTS

NOTICES

It is requested that all books for review and communications for the Editor be addressed to the Director-General, Meteorological Office, London Road, Bracknell, Berkshire, and marked "for Meteorological Magazine."

The responsibility for facts and opinions expressed in the signed articles and letters published in this magazine rests with their respective authors.

All inquiries relating to the insertion of advertisements in the Meteorological Magazine should be addressed to the Director of Publications, H.M. Stationery Office, Atlantic House, Holborn Viaduct, London E.C.1. (Telephone: CITy 9876, extn 147).

Printed in England by S. Cockburn & Son Ltd., Ossett, Yorks.
and published by

HER MAJESTY'S STATIONERY OFFICE

Three shillings monthly **Annual subscription 39s. including postage**

S.O. Code No. 40-43-64-2